4.1.1.1.3



# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2176

## AN ANALYSIS OF THE NORMAL ACCELERATIONS AND AIRSPEEDS OF A FOUR-ENGINE AIRPLANE TYPE IN POSTWAR COMMERCIAL TRANSPORT OPERATIONS ON TRANS-PACIFIC AND CARIBBEAN - SOUTH AMERICAN ROUTES

By Thomas L. Coleman and Paul W. J. Schumacher

Langley Aeronautical Laboratory
Langley Air Force Base, Va.



NACA

Washington
August 1950

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2176

# AN ANALYSIS OF THE NORMAL ACCELERATIONS AND AIRSPEEDS OF A FOUR-ENGINE AIRPLANE TYPE IN POSTWAR COMMERCIAL TRANSPORT OPERATIONS ON TRANS-PACIFIC AND CARIBBEAN - SOUTH AMERICAN ROUTES

By Thomas L. Coleman and Paul W. J. Schumacher

## SUMMARY

Normal-acceleration and airspeed data taken on several transport airplanes of a four-engine type during postwar commercial operations on trans-Pacific and Caribbean - South American routes of the same airline are analyzed. The results indicate that the acceleration increment corresponding to the limit-gust-load-factor increment may be exceeded, on the average, twice in about $5.6 \times 10^6$ flight miles for the Caribbean - South American operations and twice in about $2 \times 10^9$ flight miles for the trans-Pacific operations. The larger accelerations for the Caribbean - South American operations appear to result about equally from the lower operating weight, more severe gusts encountered, and higher airspeeds in rough air. The possibility of a trend toward a more severe flight load and gust history for postwar commercial transport airplanes, as indicated by previous work, is not substantiated by the present results. The never-exceed speed used by the airline, 250 miles per hour, may be exceeded, on the average, once in about $10^5$ flight miles for the Caribbean - South American operations and once in about $10^6$ flight miles for the trans-Pacific operations.

## INTRODUCTION

Data on imposed flight loads, operating speeds, and gusts experienced by commercial transport airplanes that were operated during the prewar period have formed the basis for gust load design requirements. With the introduction of new airplane types during the postwar period and changes observed in operating practices, appreciable doubt existed that postwar flight histories could effectively be predicted on the basis of prewar data. A program was initiated, therefore, to obtain statistical data from which imposed flight loads, operating speeds, and gust history of postwar commercial transport airplanes could be deduced.

The results of an analysis of the first postwar sample of normal acceleration and airspeed data obtained from the V-G program have been reported in reference 1. To the extent that the results of that analysis could be taken as being representative of postwar operations, a trend was indicated toward more severe imposed flight loads and gust encounters for postwar commercial transport airplanes.

As a further step toward determining the level of imposed flight loads and gust history of postwar commercial transport airplanes, other normal acceleration and airspeed data taken on another airplane type during operations on trans-Pacific and Caribbean - South American routes of a different airline from the data of reference 1 have been analyzed and the results presented herein.

## SYMBOLS

| | |
|---|---|
| $K$ | gust-alleviation factor |
| $U_e$ | effective gust velocity, feet per second |
| $V_L$ | design maximum level-flight speed, miles per hour (indicated) |
| $V_{max}$ | maximum indicated airspeed on V-G record, miles per hour |
| $V_o$ | indicated airspeed at which maximum positive or negative acceleration increment occurs on V-G record, miles per hour |
| $V_p$ | probable airspeed at which maximum recorded acceleration increment can be expected to occur, miles per hour (indicated) |
| $\Delta n_{max}$ | maximum positive or negative acceleration increment on V-G record, g units |
| $\bar{V}_{max}$, $\bar{V}_o$, $\overline{\Delta n}_{max}$ | average values of distributions of $V_{max}$, $V_o$, and $\Delta n_{max}$, respectively |
| $\sigma_v$, $\sigma_o$, $\sigma_{\Delta n}$ | standard deviations of distributions of $V_{max}$, $V_o$, and $\Delta n_{max}$, respectively |
| $\alpha_v$, $\alpha_o$, $\alpha_{\Delta n}$ | coefficients of skewness of distributions of $V_{max}$, $V_o$, and $\Delta n_{max}$, respectively |

| | |
|---|---|
| $T$ | average flight time per record, hours |
| $P_V$ | probability that maximum indicated airspeed for a record will equal or exceed a given value |
| $P_{\Delta n}$ | probability that maximum positive or negative acceleration increment for a record will equal or exceed a given value |
| $\Delta n_{LLF}$ | acceleration increment corresponding to limit-gust-load-factor increment |
| $\Delta n_{37.5K}$ | acceleration increment due to 37.5K feet per second gust at $V_p$ |

## APPARATUS AND SCOPE OF DATA

The data were obtained by means of the NACA V-G recorder which scribes on a smoked record plate an envelope of the simultaneous values of airspeed and acceleration (reference 2). The V-G records were taken on several airplanes of a four-engine type during postwar commercial transport operations on two divisions of one airline.

The airplanes were operated from San Francisco to Australia and the Orient on one route and from Miami over the Caribbean region and into South America on the other route. Information supplied by the airline indicated that, for the trans-Pacific operations, the average operating weight was 59,500 pounds and the average operating altitude was 8,000 to 10,000 feet. For the Caribbean - South American operations the average operating weight was 55,000 pounds and the average time per flight (overhead to overhead) was three hours. Information on the average time per flight for the trans-Pacific operations and the average operating altitude for the Caribbean - South American operations was not supplied by the airline.

Table I gives a breakdown by route and airplane of the records available for analysis and the records used in the analysis. As shown in the table, 84 records representing 19,740 flight hours on the trans-Pacific route and 34 records representing 8,656 flight hours on the Caribbean - South American route were available for analysis. Since the method of analysis requires a reasonably constant number of flight hours per record for a given sample (reference 3), 14 records from the trans-Pacific data and 7 records from the Caribbean - South American data were not included in the analysis because the number of flight hours did not fall within the recommended range. Also, one record from the trans-Pacific data with a maximum recorded indicated airspeed of 276 miles per hour was excluded since, according to information furnished by the airline, this high airspeed probably was recorded on a test flight. Consequently, the analysis utilized 69 records representing 15,951 flight hours of trans-Pacific operations and 27 records representing 6,677 flight hours of Caribbean - South American operations. For these records, the range of flight hours per record was 180 to 311 for the trans-Pacific data and 218 to 300 for the Caribbean - South American data. The records analyzed covered the period from August 1947 to April 1949 for the trans-Pacific route and from November 1947 to May 1949 for the Caribbean - South American route.

The characteristics of the airplanes which were used in the analysis are given in the following table:

| | |
|---|---|
| Maximum take-off weight, pounds | 70,700 |
| Wing area, square feet | 1461 |
| Wing span, feet | 117.5 |
| Mean aerodynamic chord, feet | 13.6 |
| Slope of lift curve, per radian (value used in design) | 4.699 |
| Aspect ratio | 9.45 |
| Gust alleviation factor, K (from reference 4) | 1.188 |
| Limit gust load factor, g units (computed) | 2.50 |
| Design maximum level-flight speed at sea level, miles per hour | 250 |
| Maximum level-flight speed, miles per hour | 209 to 250[a] |
| Never-exceed speed, miles per hour | 250 to 300[a] |

[a]Maximum permissible airspeed within these ranges depends upon weight condition of the airplane.

The slope of the lift curve was obtained from the manufacturer's design data and the maximum take-off gross weight, from the operator. The limit-gust-load factor of 2.50g was computed with the gust-load-factor formula of reference 4 and is based on a gross weight of 70,700 pounds and on an effective gust velocity $U_e$ of 30K feet per second at the design maximum speed in level flight $V_L$ of 250 miles per hour. Recent unpublished gust-tunnel data have indicated the value of K for the present airplane as determined from reference 4 to be in good agreement with the value obtained experimentally for a scale model of the airplane.

The maximum speed in level flight varies from 209 to 250 miles per hour and the never-exceed speed for the airplane varies from 250 to 300 miles per hour with the maximum permissible values within these ranges depending upon the weight conditions of the airplane. It was learned from contact with personnel of the airline, however, that operating practices for both routes call for a maximum level-flight speed of 209 miles per hour and a never-exceed speed of 250 miles per hour.

## ANALYSIS AND RESULTS

The analytical procedures used in the analysis are described in reference 3. The method of analysis used requires that from each V-G record the following values be read: the maximum positive and negative acceleration increments $\Delta n_{max}$, the speeds corresponding to the maximum acceleration occurrences $V_o$, and the maximum speed recorded $V_{max}$. Table II gives the frequency distributions by route of these variables with the statistical parameters of each distribution: namely, the average values, the standard deviation $\sigma$, and the coefficient of skewness $\alpha$. Pearson type III probability curves (reference 5), which in the past have given reasonable representations of this type of data, were fitted to the observed distributions by use of the statistical parameters. The results obtained are shown in figures 1, 2, and 3 for the $\Delta n_{max}$, $V_{max}$, and $V_o$ distributions, respectively.

Recent work reported in reference 6 has indicated that the distribution of extreme values may be expected, under certain conditions, to yield reliable representations of observed distributions of maximum acceleration increments from V-G data and to provide a reliable basis for extrapolation. Distributions of extreme values were fitted to the present $\Delta n_{max}$ data in accordance with the method outlined in the reference. The curves obtained on the basis of distribution of extreme values, however, did not adequately represent the data and consequently were not used in the analysis.

The Pearson type III probability curves fitted to the distributions of $\Delta n_{max}$ and $V_{max}$ (figs. 1 and 2) were transformed to curves of average flight miles required to equal or exceed given values of acceleration increment and airspeed by multiplying $1/P_{\Delta n}$ and $1/P_v$ by an assumed cruising speed of 180 miles per hour and the average flight hours per record $\tau$. Inasmuch as the present analysis is concerned mainly with the largest values of acceleration increments and airspeeds attained, only the part of the transformed curves for the larger acceleration or airspeed values of the distributions is shown in figures 4 and 5. The limitations of using the transformed $\Delta n_{max}$ and $V_{max}$ probability curves as curves of average flight miles to equal or exceed given values of acceleration increment and airspeed have been discussed in reference 1. This reference indicated that estimates of the flight miles to exceed the larger values of acceleration increments and airspeeds based on the distribution of the observed maximums are not seriously in error.

In order to obtain a measure of the gust history for the present operations, the flight miles required to exceed the acceleration increment due to an effective gust velocity of 37.5K feet per second at $V_p$

were obtained and are shown in figure 4. The most probable speeds for maximum acceleration increment occurrence $V_p$ shown in figure 3 were calculated from the statistical parameters of the $V_o$ distributions (table II) to be 177 and 179 miles per hour for the trans-Pacific and Caribbean - South American data, respectively. The use of $V_p$ as a representative airspeed for each airplane allows the reduction of acceleration increment data to apparent gust data and permits an evaluation of the gust history which is independent of the flight speed. The particular value of 37.5K feet per second used for the effective gust velocity was chosen so that the resulting acceleration increment would equal the limit-gust-load-factor increment if the airplane were flown at 0.8 of the design maximum level-flight speed.

## PRECISION

The precision of the V-G recorder and the limitations of the method of analysis are discussed in reference 7. The inherent instrument errors are assumed not to exceed ±0.2g for acceleration nor 3 percent of the maximum airspeed range of the instrument.

Inasmuch as the data for the trans-Pacific route did not extend to the acceleration increment corresponding to the limit-gust-load-factor increment, it was necessary to estimate the frequency of exceeding this limiting value by extrapolating the data. On the basis of past experience, this extrapolation is felt to be justified provided that the estimates thus obtained are used only as an indication of the order of magnitude. For the Caribbean - South American data, which extended to the limiting value, the estimated flight miles to exceed the acceleration increment corresponding to the limit-gust-load-factor increment and never-exceed speed are thought to be reliable within a range extending from one-third to three times the values quoted.

The adequacy of accelerometer measurements at the center of gravity for measuring gust loads on present-day transport airplanes may be open to some question inasmuch as structural dynamic response may have a significant effect on the accelerations measured at this location. Since the relative dynamic-response effects on peak accelerometer measurements at the center of gravity for various airplanes are not known, the full significance of comparisons made between the present results and past results may not be realized; however, for comparison between the present two sets of data, which were obtained on the same type of airplane at about the same weight conditions, any dynamic response effects would be expected to be of equal magnitude. Although the absolute values of acceleration increments for both sets of data may be in error due to dynamic response, the difference in these values would be expected to be of the correct magnitude and thus reflect the relative accelerations for the two routes.

## DISCUSSION

Examination of figure 4 indicates that, for this airplane type operated on the Caribbean - South American route, the acceleration increment corresponding to the calculated limit-gust-load-factor increment of 1.5g may be exceeded, on the average, twice in about $5.6 \times 10^6$ flight miles. An extreme extrapolation of the data for the trans-Pacific route (fig. 4) indicates that the chance of exceeding this acceleration increment for this airplane and route is decidedly remote, being of the order of magnitude of twice in $2 \times 10^9$ flight miles. Figure 4 also indicates that, for a given flight mileage, the maximum acceleration increment for the Caribbean - South American data is roughly 30 percent greater than that for the trans-Pacific data. The large differences indicated in the frequency of attaining the larger acceleration increments for the two sets of data appear significant and may be considered to indicate substantial differences between the recorded accelerations for the two sets of operations. This conclusion is further supported when it is recalled that both data samples covered approximately the same period and that the data for the trans-Pacific operations, which indicated the lower acceleration, represent over twice as many flight miles as the data for the Caribbean - South American operations. Inasmuch as the frequency with which the larger acceleration increments are obtained can, in general, be largely attributed to operating weight, operating practices with respect to airspeed in rough air, and gusts encountered, consideration will be given to these factors and to their effects on the frequency with which the larger acceleration increments were attained for the present operations.

The average operating weights for the present data were indicated by the airline to be 59,500 pounds for the trans-Pacific operations and 55,000 pounds for the Caribbean - South American operations or a difference in average operating weight for the two routes of about 8 percent. If the gust intensities and airspeed operating practices were the same, the maximum acceleration increments for a given number of flight miles for the Caribbean - South American data would be expected to be about 8 percent greater than those for the trans-Pacific data. As noted in the foregoing paragraph, however, the maximum acceleration increment for a given number of flight miles for the Caribbean - South American data is roughly 30 percent greater than that for the trans-Pacific data. It is apparent, therefore, that of the 30 percent difference in the recorded accelerations for the two routes only about 10 percent is due to differences in operating weights and that the remaining 20 percent difference is due to differences in airspeeds in rough air and gust intensities.

The airspeeds in rough air for the present operations are represented in figure 3 by the distributions of $V_o$. Examination of the figure shows that the Caribbean - South American operations have the greater tendency toward higher airspeeds in rough air. These distributions suggest that of the 30 percent difference noted in the maximum acceleration increments for the two sets of data perhaps about 10 percent may be attributed to the different speed practices in rough air for the two sets of operations.

Past work (reference 1) has utilized the concept of the flight miles required to exceed the acceleration increment due to an effective gust velocity of 37.5K feet per second at the most probable speed of maximum acceleration increment occurrence $V_p$ as a measure of the gust history. Examination of figure 4 indicates that this acceleration increment may be exceeded, on the average, in about $90 \times 10^6$ flight miles for the trans-Pacific and $10^6$ flight miles for the Caribbean - South American operation. Although it is evident that the more severe gusts encountered for the Caribbean - South American operations would tend to cause a higher frequency of exceeding the larger acceleration increments, the magnitude of this effect cannot be simply determined since it is interrelated with airspeed operating practices in rough air. Since, however, it has previously been indicated that differences in operating weight and airspeeds in rough air account for about two-thirds of the difference in acceleration history for the two routes, the remaining 10 percent difference would seem to be attributable to differences in the gust history for the two operations.

The foregoing discussion has indicated that the maximum acceleration increment for a given number of flight miles for the two sets of present operations differ by about 30 percent. The larger accelerations for the Caribbean - South American operations appear to result about equally from the lower average operating weight, higher airspeeds in rough air, and more severe gusts for this route than for the trans-Pacific route.

Based on an analysis of the first postwar sample of acceleration and airspeed data, which was obtained on L-649 airplanes operated over the Eastern part of the United States, reference 1 indicated the possibility of a trend toward more severe imposed flight loads and increased apparent gust history for postwar commercial transport airplanes. For comparison, the flight miles to exceed the acceleration increment corresponding to the limit-gust-load-factor increment $\Delta n_{LLF}$ and the acceleration increment $\Delta n_{37.5K}$ due to a 37.5K feet per second gust at $V_p$ for the present data and the data for the L-649 airplane are given in the following table. For general information, the range in the corresponding values for prewar and wartime operations is also included in the table.

| Operation | Flight miles to exceed twice | |
|---|---|---|
| | $\Delta n_{LLF}$ | $\Delta n_{37.5K}$ |
| L-649 airplane (reference 1) | $0.58 \times 10^6$ | $0.66 \times 10^6$ |
| Present trans-Pacific route | $2000 \times 10^6$ | $90 \times 10^6$ |
| Present Caribbean - South American route | $5.6 \times 10^6$ | $1 \times 10^6$ |
| Range for prewar period | $3.4$ to $920 \times 10^6$ | $3.1$ to $43 \times 10^6$ |
| Range for wartime period | $2.2$ to $5.6 \times 10^6$ | $0.72$ to $5 \times 10^6$ |

Consideration of the values in the table indicates that, for the Caribbean - South American data, the intensity of the imposed flight loads as measured by the frequency of exceeding the acceleration increment corresponding to the limit-gust-load-factor increment and the gusts experienced are slightly less severe than those for the L-649 airplane data. For the trans-Pacific data the probability of exceeding the defined limit values is remote. Thus, inasmuch as the three postwar samples of data do not show a consistent level of imposed flight loads and gust history, the present results do not substantiate the possibility of a trend toward more severe imposed flight loads and gust encounters for postwar commercial transport airplanes.

Consideration of the maximum airspeeds attained during the present operations as summarized in figure 5 indicates that the never-exceed speed used by the airline, 250 miles per hour, may be exceeded once in about $10^5$ flight miles for the Caribbean - South American operations and once in about $10^6$ flight miles for the trans-Pacific operations. The present results appear to substantiate earlier indications, references 1 and 8, that the selection of a never-exceed speed does not insure that this value will not be exceeded during normal commercial operations of a transport airplane.

## CONCLUSIONS

Analysis of normal acceleration and airspeed data taken on several airplanes of a four-engine type during postwar commercial transport operations on trans-Pacific and Caribbean - South American routes of the same airline has indicated the following:

1. For the present operations the acceleration increment corresponding to the calculated limit-gust-load-factor increment of 1.5g may be exceeded, on the average, twice in about $5.6 \times 10^6$ flight miles for the Caribbean - South American data. For the trans-Pacific data the frequency of exceeding this acceleration increment is decidedly remote, being on the order of magnitude of twice in $2 \times 10^9$ flight miles.

2. The larger accelerations for the Caribbean - South American operations appear to result about equally from the lower operating weight, more severe gust history, and higher airspeeds in rough air.

3. The possibility of a trend toward more severe imposed flight loads and increased apparent gust encounters for postwar commercial transport airplanes as indicated by previous work is not substantiated by the present results.

4. The never-exceed speed used by the airline, 250 miles per hour, may be exceeded, on the average, once in about $10^5$ flight miles for the Caribbean - South American operations and once in about $10^6$ flight miles for the trans-Pacific operations.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va., April 20, 1950

## REFERENCES


1. Coleman, Thomas L.: An Analysis of the Normal Accelerations and Airspeeds of Several Lockheed Constellation L-649 Airplanes in Postwar Commercial Transport Operations over the Eastern Part of the United States. NACA RM L9E18a, 1950.

2. Rhode, Richard V.: Gust Loads on Airplanes. SAE Jour., vol. 40, no. 3, March 1937, pp. 81-88.

3. Peiser, A. M., and Wilkerson, M.: A Method of Analysis of V-G Records from Transport Operations. NACA Rep. 807, 1945.

4. Anon: Airplane Airworthiness. Civil Aero. Manual 04, CAA, U. S. Dept. Commerce, Feb. 1, 1941, sec. 04.2121.

5. Kenney, John G.: Mathematics of Statistics. Pt. II. D. Van Nostrand Co. Inc., 1939, pp. 49-51.

6. Press, Harry: The Application of the Statistical Theory of Extreme Values to Gust-Load Problems. NACA TN 1926, 1949.

7. Peiser, A. M., and Walker, W. G.: An Analysis of the Airspeeds and Normal Accelerations of Boeing S-307 Airplanes in Commercial Transport Operation. NACA TN 1141, 1946.

8. Steiner, Roy: An Analysis of Airspeeds and Mach Numbers Attained by Lockheed Constellation Airplanes in Transcontinental Operations during the Early Summer of 1946. NACA RM L7C06, 1947.

TABLE I

SUMMARY OF V-G RECORDS SUPPLIED AND USED IN ANALYSIS

| Airplane | Records available | | Records used | | | |
|---|---|---|---|---|---|---|
| | Number | Total flight hours | Number | Total flight hours | Average flight hours per record, $\tau$ | Range of record flight hours |
| Trans-Pacific route | | | | | | |
| a | 12 | 3,127 | 10 | 2,287 | 229 | 192 to 254 |
| b | 11 | 2,731 | 9 | 2,096 | 233 | 210 to 252 |
| c | 10 | 2,660 | 8 | 1,823 | 228 | 195 to 253 |
| d | 10 | 2,016 | 8 | 1,812 | 227 | 180 to 311 |
| e | 4 | 890 | 4 | 890 | 223 | 203 to 243 |
| f | 3 | 892 | 2 | 441 | 221 | 211 to 230 |
| g | 8 | 1,679 | 7 | 1,677 | 239 | 205 to 253 |
| h | 12 | 2,853 | 12 | 2,853 | 238 | 222 to 253 |
| i | 6 | 1,507 | 4 | 925 | 231 | 186 to 257 |
| j | 8 | 1,385 | 5 | 1,147 | 229 | 223 to 241 |
| Totals | 84 | 19,740 | 69 | 15,951 | 231 | 180 to 311 |
| Caribbean - South American route | | | | | | |
| k | 14 | 3,472 | 11 | 2,713 | 247 | 225 to 258 |
| l | 5 | 1,252 | 4 | 945 | 236 | 227 to 247 |
| m | 12 | 3,180 | 9 | 2,267 | 252 | 218 to 300 |
| n | 3 | 752 | 3 | 752 | 251 | 245 to 257 |
| Totals | 34 | 8,656 | 27 | 6,677 | 247 | 218 to 300 |

TABLE II

FREQUENCY DISTRIBUTIONS AND STATISTICAL

PARAMETERS OF $\Delta n_{max}$, $V_{max}$, $V_o$

| $\Delta n_{max}$ | | | $V_{max}$ | | | $V_o$ | | |
|---|---|---|---|---|---|---|---|---|
| Acceleration increment (g units) | Frequency | | Airspeed (mph) | Frequency | | Airspeed (mph) | Frequency | |
| | Trans-Pacific | Caribbean - South American | | Trans-Pacific | Caribbean - South American | | Trans-Pacific | Caribbean - South American |
| 0.3 to 0.4 | 1 | – | 220 to 225 | 6 | – | 120 to 130 | 1 | 2 |
| .4 to .5 | 8 | 3 | 225 to 230 | 6 | – | 130 to 140 | 9 | 6 |
| .5 to .6 | 21 | 1 | 230 to 235 | 17 | – | 140 to 150 | 7 | 2 |
| .6 to .7 | 29 | 5 | 235 to 240 | 19 | 2 | 150 to 160 | 7 | 2 |
| .7 to .8 | 32 | 10 | 240 to 245 | 12 | 6 | 160 to 170 | 30 | 5 |
| .8 to .9 | 26 | 8 | 245 to 250 | 8 | 7 | 170 to 180 | 33 | 11 |
| .9 to 1.0 | 14 | 6 | 250 to 255 | 0 | 5 | 180 to 190 | 34 | 9 |
| 1.0 to 1.1 | 4 | 8 | 255 to 260 | 0 | 5 | 190 to 200 | 10 | 6 |
| 1.1 to 1.2 | 3 | 5 | 260 to 265 | 1 | 0 | 200 to 210 | 5 | 5 |
| 1.2 to 1.3 | -- | 5 | 265 to 270 | -- | 2 | 210 to 220 | 2 | 1 |
| 1.3 to 1.4 | -- | 2 | -------- | -- | – | 220 to 230 | -- | 3 |
| 1.4 to 1.5 | -- | 1 | -------- | -- | – | 230 to 240 | -- | 2 |
| Total | 138 | 54 | Total | 69 | 27 | Total | 138 | 54 |
| $\overline{\Delta n}_{max}$ | 0.735 | 0.920 | $\overline{V}_{max}$ | 236.5 | 249.9 | $\overline{V}_o$ | 172.9 | 178.3 |
| $\sigma_{\Delta n}$ | 0.162 | 0.239 | $\sigma_V$ | 7.64 | 7.74 | $\sigma_o$ | 17.75 | 27.62 |
| $\alpha_{\Delta n}$ | 0.216 | 0.068 | $\alpha_V$ | 0.293 | 0.543 | $\alpha_o$ | -0.419 | -0.053 |

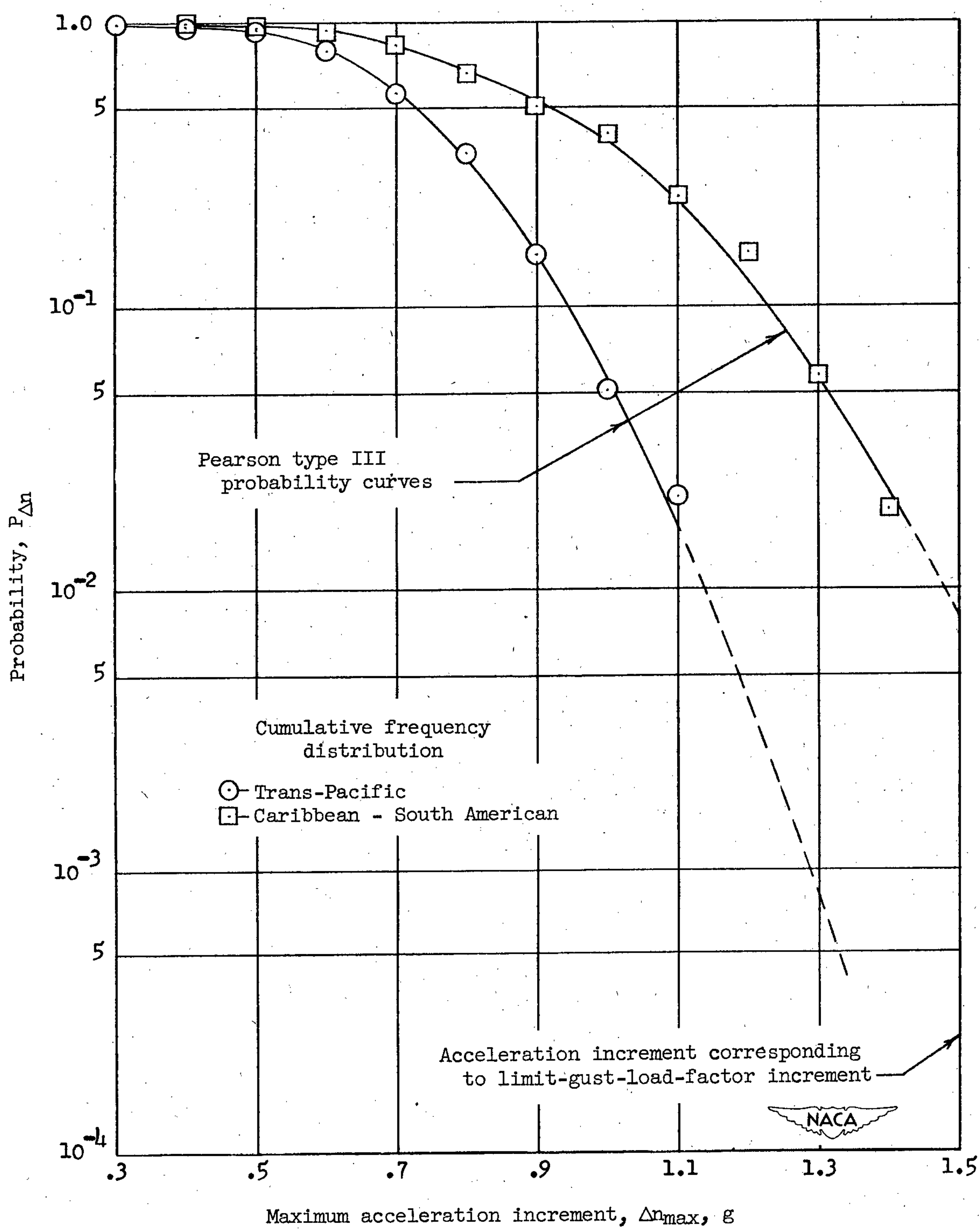


Figure 1.- Probability that the maximum positive or negative acceleration increment on a V-G record will equal or exceed a given value.

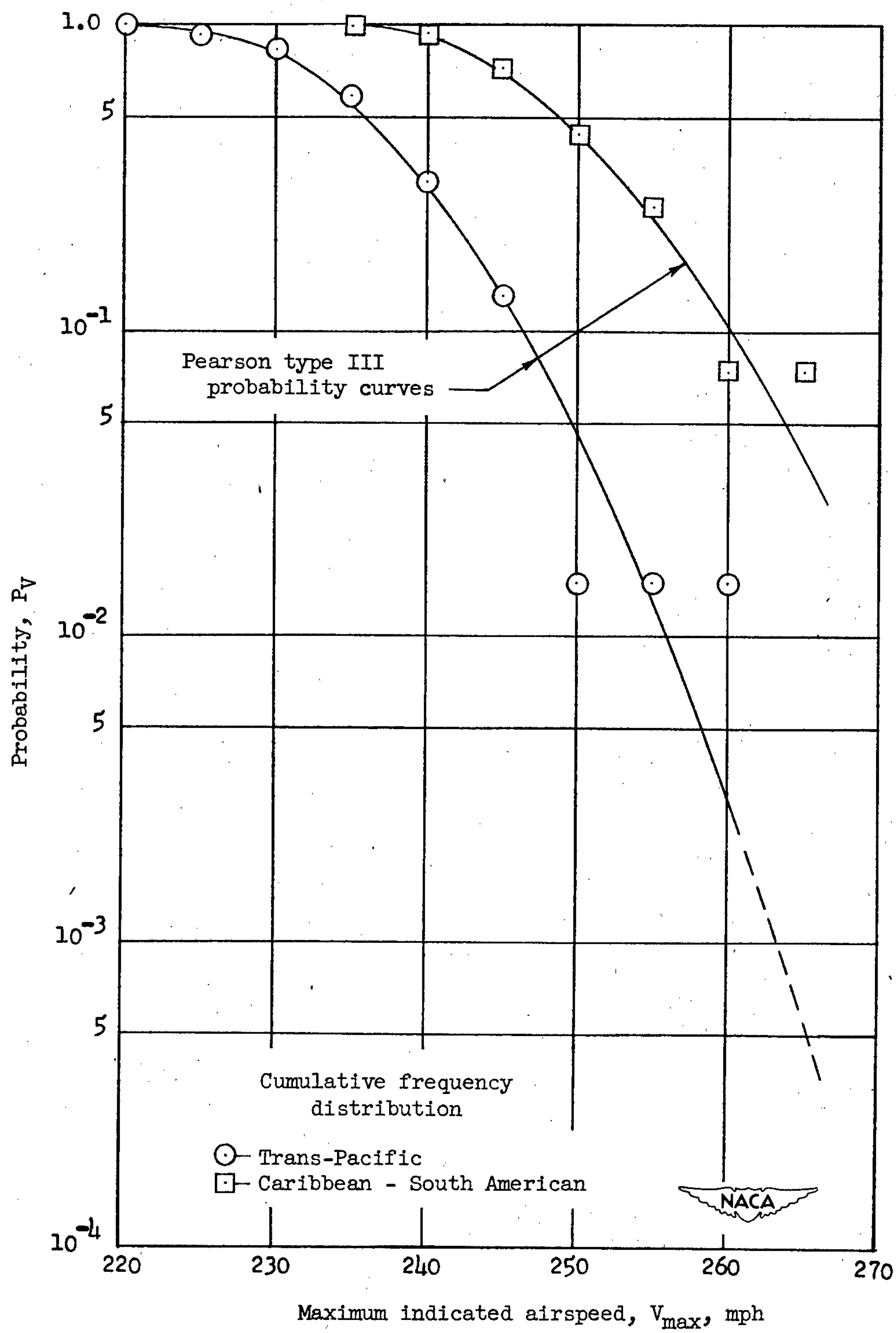


Figure 2.- Probability that the maximum indicated airspeed on a record will equal or exceed a given value.

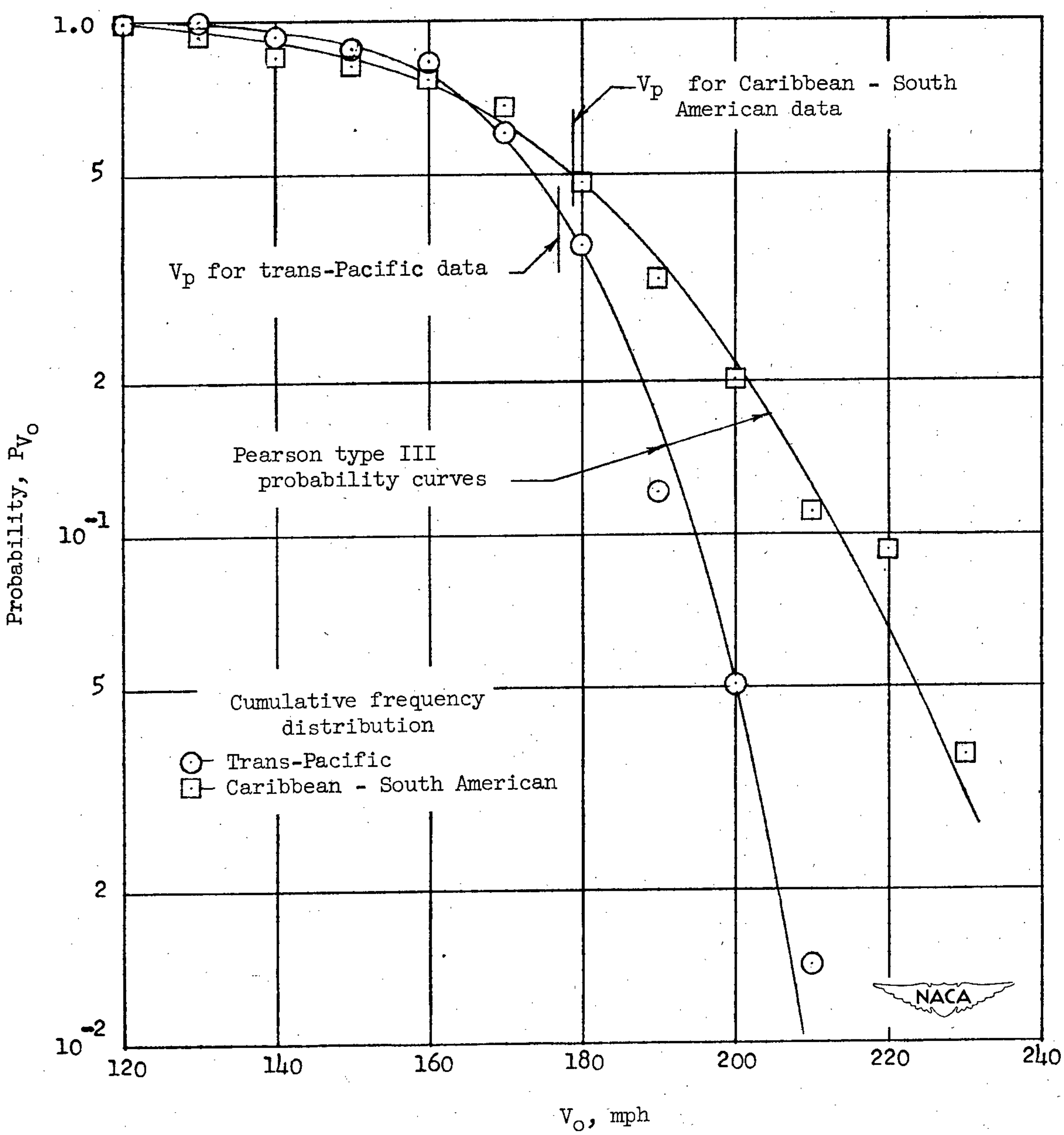


Figure 3.- Probability that indicated airspeed at which maximum acceleration increment is experienced will exceed or equal a given value.

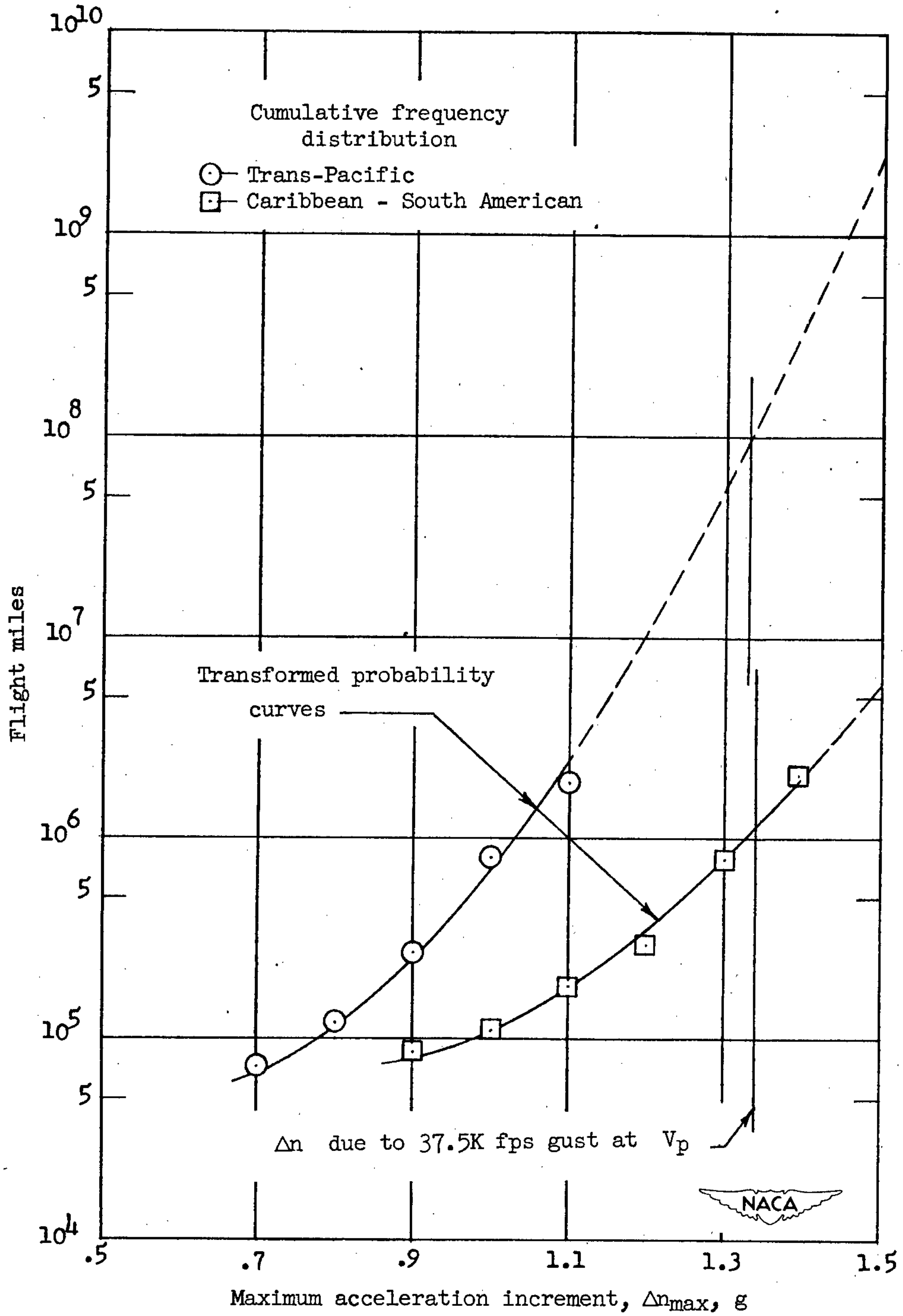


Figure 4.- Average flight miles required for a maximum positive and negative acceleration increment to equal or exceed a given value.

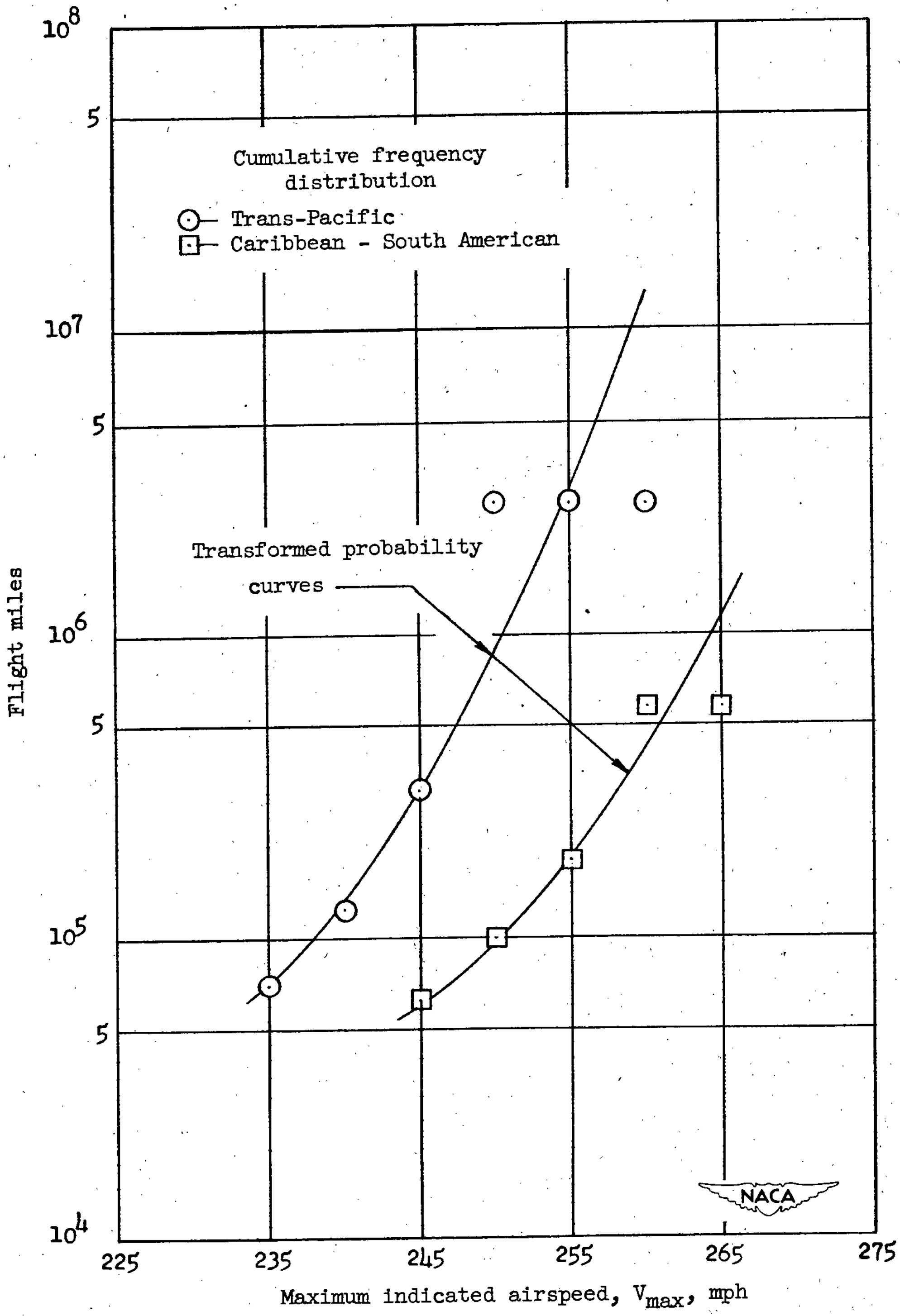


Figure 5.- Average flight miles required for the maximum indicated airspeed on a record to equal or exceed a given value.